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A Comparison of the Temporal Characteristics of LCS, LCoS, Laser, And CRT Projectors

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14. ABSTRACT

We have measured the temporal response of a commercial liquid crystal on silicon (LCoS) projector, and have compared it to that of commercial liquid crystal display (LCD) and cathode ray tube (CRT) projectors, as well as to a prototype laser projector. The faster temporal response of LCoS displays, as compared to more conventional LCDs, has not been considered a major factor in their commercial use, and so individual pixels are not turned on and off in these devices as quickly as the technology allows. Based on informal discussions with LCoS manufacturers and users, it appears that changes can be made in the LCoS display electronics to reduce pixel response times in order to sufficiently reduce smearing in moving simulator images.

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A COMPARISON OF THE TEMPORAL CHARACTERISTICS OF LCD, LCoS, LASER, AND CRT PROJECTORS

SUMMARY

We have measured the temporal response of a commercial liquid crystal on a silicon (LCoS) projector, and have compared it to that of commercial liquid crystal display (LCD) and cathode ray tube (CRT) projectors, as well as to a prototype laser projector. The faster temporal response of LCoS displays, as compared to more conventional LCDs, has not been considered a major factor in their commercial use, and so individual pixels are not turned on and off in these devices as quickly as the technology allows. Based on informal discussions with LCoS manufacturers and users, it appears that changes can be made in the LCoS display electronics to reduce pixel response times in order to sufficiently reduce smearing in moving simulator images.

BACKGROUND / INTRODUCTION

LCD projectors are smaller and less expensive than CRT projectors, and have been considered as replacements for the CRT projectors currently used in the Mobile Modular Display for Advanced Research and Training (M2DART) which is an eight-channel, rear-projection visual display system designed for use as with single-seat cockpit simulators. However, standard LCDs have a slower temporal response than CRTs, and as a result moving images often appear smeared or blurred. LCoS is a new type of LCD which may have sufficient temporal response for flight simulator applications.

We have measured the temporal response of a commercial LCoS projector, and have compared that response with those of a standard LCD projector, a CRT projector, and a prototype laser projector.

METHOD

We evaluated an LCoS projector (VDC, Model Marquee 1500 Sim Ultra), an LCD projector (3M, Model MP8765), a CRT projector (Barco, Model 808), and a prototype, green only laser projector (Evans & Sutherland). All test stimuli were imaged on a rear-projection screen (Proscreen, 1.2 gain).

The temporal response of the various projectors was measured using the circuits shown in Figures 1 and 2. The circuit of Figure 1 is our implementation of a standard configuration [1], except that a base-collector junction of the phototransistor (Model

L14G3, QT Optoelectronics) was used as a photodiode. Shown in Figure 2 is a diagram of a second photodiode circuit that was used to measure the higher temporal responses of the CRT and laser projectors. The first stage of the circuit, centered on the first op-amp following the high-speed photodiode (Model BPX-65, CentroVision, Inc.), served to operate the photodiode in the reverse biased, photoconductive mode. Since the gain of the first stage was kept low to improve the frequency response, a second stage was added to amplify its output. The aperture of the photodiode was about 4 mm, and it was placed directly against the rear-projection screen.

Due to the inherent ambiguities in comparing the rise-times of responses that have not reached their peak, we compare here only the general features of the temporal responses of the projectors tested. Also, we were unable to obtain a light modulation device fast enough to calibrate the rise-time of the photodiode circuits. Although we have no reason to believe that the circuits are not fast enough to accurately measure the temporal responses of the faster projectors tested (i.e., the CRT and laser projectors), we suggest that no conclusions concerning *absolute* temporal response be drawn from the measurements presented here.

RESULTS AND DISCUSSION

The light output obtained from the LCD projector in response to 16.7 msec and 33.3 msec test stimuli are shown in Figures 3 and 4, respectively. These test stimuli were obtained by flashing a 0.5” × 0.5” white square using a duty cycle less than 50%. The LCD response increases about 315 mV while the 16.7 msec stimulus is on, and to about 350 mV while the 33.3 msec stimulus is on. The response to the 33.3 msec stimulus reaches 80% of its peak response in about 10 ms. For both stimuli, the response returns to its baseline level in about 2 msec after stimulus offset. The waveform of Figure 3 is similar to the initial portion of that of Fig. 4, suggesting similar on-times.

The light output obtained from the LCoS projector in response to 16.7 msec and 33.3 msec test stimuli are shown in Figures 5 and 6, respectively. These test stimuli again were flashed white squares as described earlier. The LCoS response increases about 200 mV and 320 mV for the 16.7 msec and 33.3 msec stimuli, respectively. For both stimulus durations, the response reaches 80% of its peak amplitude in about 5 msec, and it returns to its baseline level in about 2 msec after stimulus offset.

Two LCoS waveform measurements that may be relevant to the use of these projectors in display applications requiring high temporal response are shown in Figures 7 and 8. The waveform of Figure 7 was obtained using a steady white stimulus, and shows that the output of this projector is not uniform under these conditions. The amplitude of this waveform is small compared to that of Figures 3 and 4, but it might nevertheless interfere with accurate image presentation in some applications. The waveform of Figure 8 was obtained by flashing the same white test stimulus described above at 30 Hz (i.e., at a 60 Hz frame rate) with a 50% duty cycle. The gap in the waveform represents a missed frame, which may have practical implications for motion representation.

The light output obtained from the prototype laser projector in response to a 16.7 msec test stimulus is shown in Figures 9. The laser projector reached 80% of its peak response in about 3 μsec, and the response returned to its baseline value in about 5 μsec after stimulus offset. Shown in Figure 10 is the light output of the laser projector to a static grille pattern consisting of alternating vertical columns of single pixels. The individual components of the waveform have approximately the same temporal properties as the flashed stimulus of Figure 9. The laser projector wrote effectively 7500 lines (5120 horizontal pixels plus retrace) at 60 Hz, giving an interpixel interval of 2.2 μsec (= 16.7 msec / 7500 lines). This interval is less than the duration of the response profile of Figure 9 indicating that the laser output did not fully return to its baseline value during the presentation of the off-columns of the grille pattern. This phenomenon is evident in the waveform of Figure 10. The lines of the grille pattern are seen distributed in time due to the scanning properties of the laser projector. The differences in the amplitude of the lines is due to the optical properties of the photodetector.

The light output obtained from the CRT projector in response to a single statically displayed pixel is shown in Figure 11. The CRT response increases to about 5 volts in about 1.3 μsec and then decreases to a near baseline level in about 10 μsec. Each pixel is addressed by the CRT electronics for about 8.7 nanosec, so the waveform shown is clearly due to the response of the CRT phosphor.

The light output obtained from the CRT projector in response to a 16.7 msec (30 Hz) test stimulus is shown in Figure 12. The pulses shown represent the horizontal raster lines visible to the photodiode in a single frame. The time course of the individual pulses is similar to that of the single pixel response shown in Figure 11. Again, the fall-off in intensity is due to the directional properties of the diode and mounting hardware.

CONCLUSIONS / RECOMMENDATIONS

The onset and offset times of the LCoS projector tested suggest that this technology is suitable for flight simulator applications requiring accurate rendering of image motion. The on-time of the LCoS projector has been increased to that of the full frame on-time, apparently in order to maximize light output. If LCoS projectors are considered as replacements for the current M2DART projectors, it is recommended that projector manufacturers be contacted in order to assess the possibility of designing circuitry to reduce the on-time per displayed image frame. It is further recommended that the LCoS technology be evaluated to determine if their light output is sufficient to compensate for the reduced per-frame on-time required to improve their temporal response.

REFERENCES / NOTES

Centrovision, Inc.see PhotodiodeTechnology section at www.centrovsion.com).

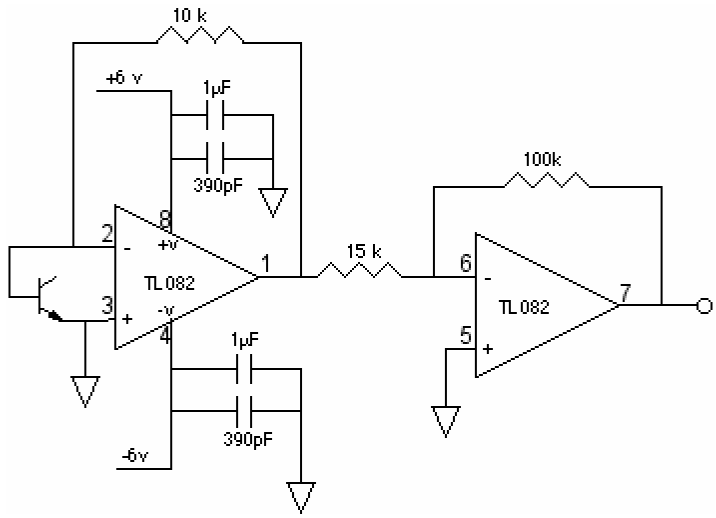

Figure 1. Photodiode and amplifier circuitry used to measure the temporal response of the LCD and LCoS projectors. In this circuit, a phototransistor is configured as a photodiode.

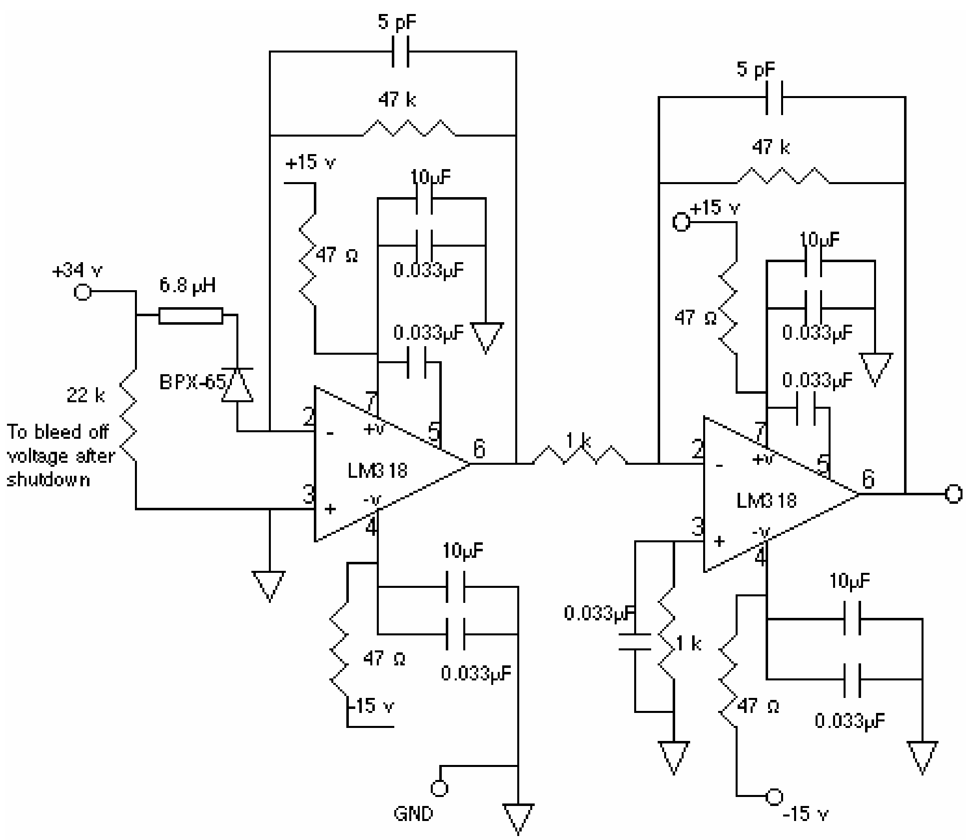

Figure 2. Photodiode and amplifier circuitry used to measure the temporal response of the laser and CRT projectors.

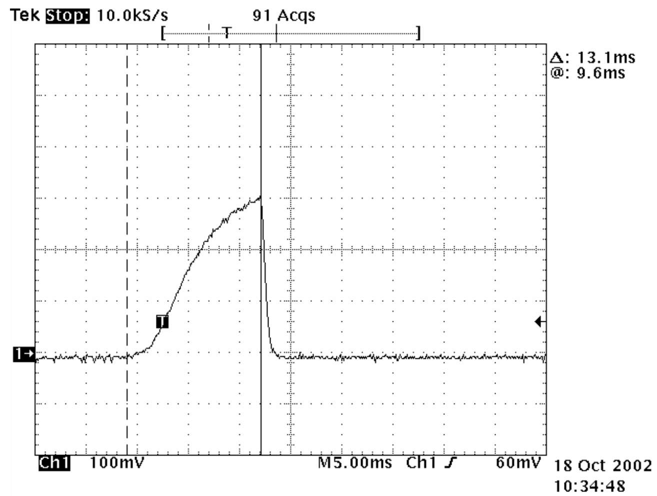

Figure 3. Light output of the ***LCD projector*** *to a 16.7 msec test stimulus. Vertical scale: 100 mV/division; Horizontal scale: 5 msec/division.*

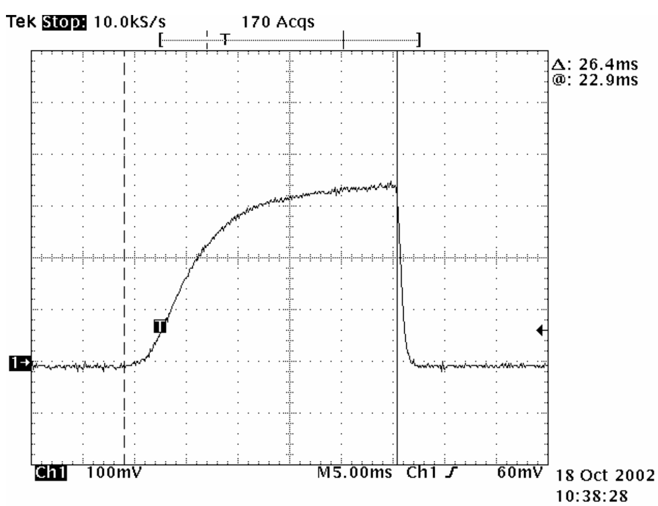

Figure 4. Light output of the ***LCD projector*** *to a 33.3 msec test stimulus. Vertical scale: 100 mV/division; Horizontal scale: 5 msec/division.*

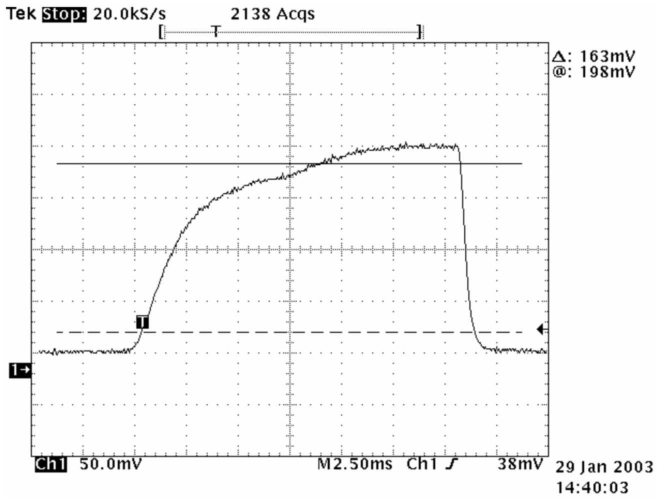

*Figure 5. Light output of the **LCoS projector** to a 16.7 msec test stimulus (i.e., a 30 Hz flashing square). Vertical scale: 50 mV/division; Horizontal scale: 2.5 msec/division.*

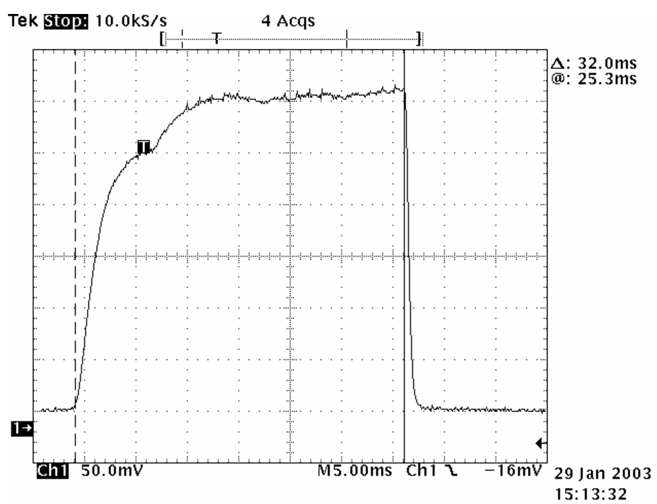

*Figure 6. Light output of the **LCoS projector** to a 33.3 msec test light (i.e., a 15 Hz flashing square). Vertical scale: 50 mV/division; Horizontal scale: 5 msec/division.*

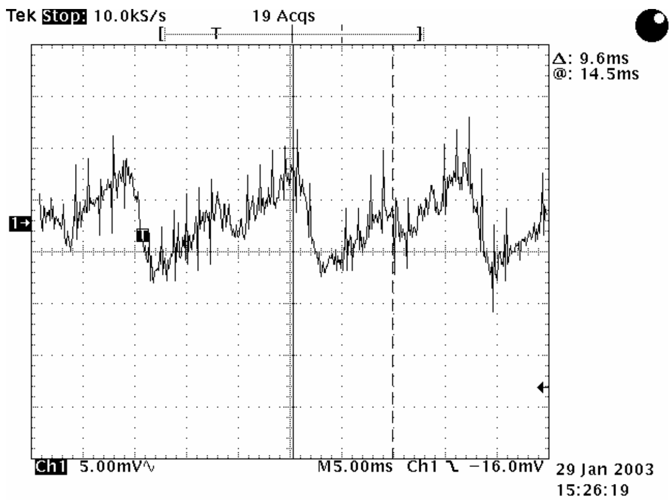

*Figure 7. Response of the **LCoS projector** to a steady test stimulus. Vertical scale: 5 mV/division; Horizontal scale: 5 msec/division.*

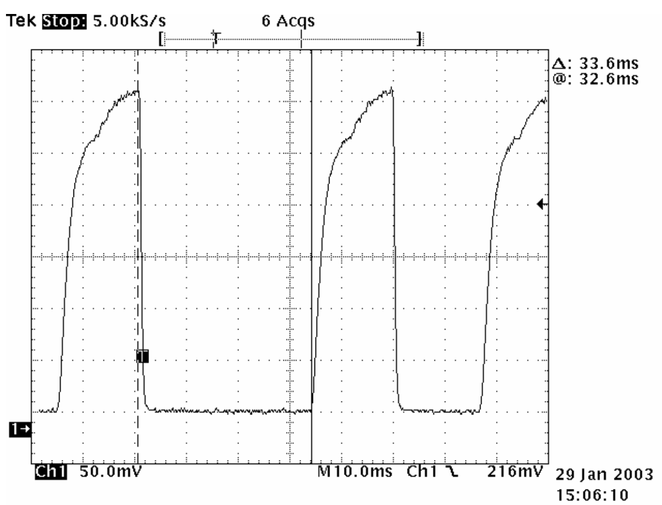

*Figure 8. An example of a missed **LCoS projector** on-frame to a one-frame on / one-frame off flashing test stimulus. Vertical scale: 50 mV/division; Horizontal scale: 10 msec/division.*

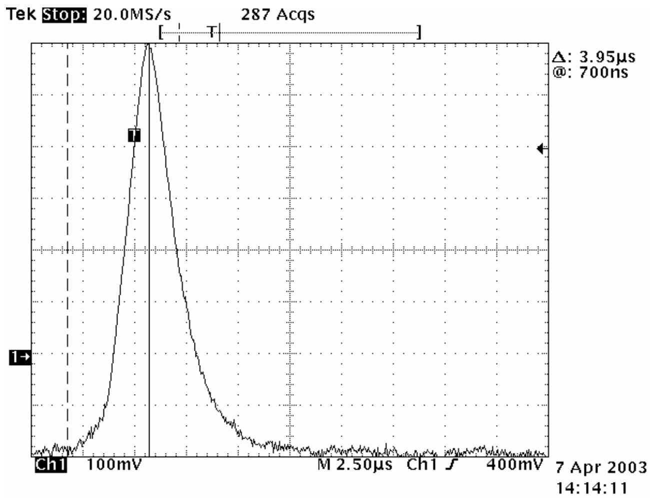

*Figure 9. Light output of the **laser projector** to a single on-frame of a single pixel that was displayed for 16.7 msec (i.e., flashing at 30 Hz). Vertical scale: 100 mV/division; Horizontal scale: 2.5 msec/division.*

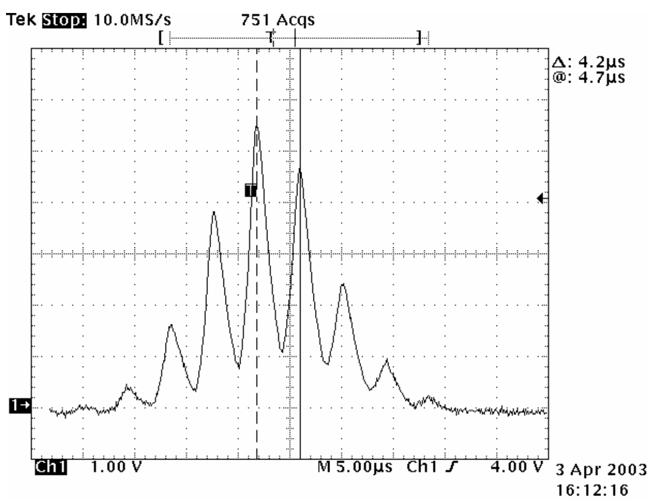

*Figure 10. Light output of the **laser projector** to a vertical grille pattern consisting of alternating on and off columns of pixels. Vertical scale: 1 V/division; Horizontal scale: 5 μsec/division.*

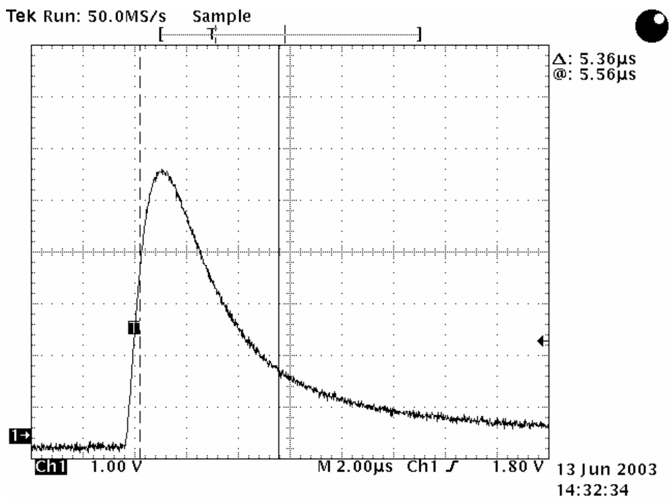

*Figure 11. Light output of the **CRT projector** to a single displayed pixel. Vertical scale: V/division; Horizontal scale: 2 μsec/division.*

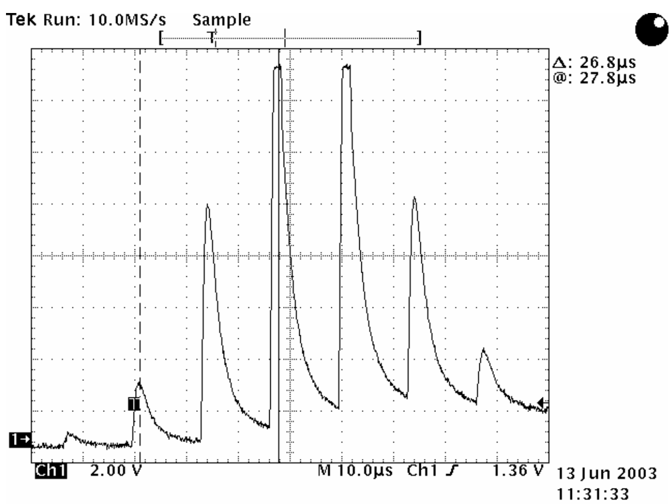

*Figure 12. Light output of the **CRT projector** to a 16.7 msec test stimulus (i.e., a 30 Hz flashing square). Vertical scale: 2 V/division; Horizontal scale: 10 μsec/division.*